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Preservation of bananas coated with cassava starch and pectin

Conservação de banana 'Prata Anã' revestida com fécula de mandioca e pectina

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Abstract: The search for alternatives to increase the shelf life of fruits using biodegradable coatings has grown in recent years, especially for fruits whose ripening process continues after harvesting, as is the case of bananas. The objective of this study is to evaluate the conservation of 'Prata Anã' bananas (*Musa* spp.) coated with cassava starch and pectin during storage at room temperature. The bananas were selected, washed and coated with starch and pectin solutions at concentrations of 0 (control) 2, 5 and 8% and stored at 25 ± 3 °C for twelve days, evaluating them every three days for mass loss, peel color, fruit firmness, total soluble solids, total titratable acidity and potential of hydrogen. The experimental design was completely randomized in a 7 x 5 factorial design (concentrations of coatings x storage periods), with three replications. Results were subjected to analysis of variance and regression analysis, and the means were compared by Tukey test at 5% probability. The coatings based on cassava starch and pectin were characterized as potential alternatives to increase the lifespan of 'Prata Anã' bananas. The concentrations 5 and 8% of both coatings stood out in the preservation of some fruit quality attributes such as color, firmness, and total soluble solids. Considering the cost/benefit ratio, the use of starch-based coatings would be more appropriate.

Keywords: *Musa* AAB, biodegradable coating, post-harvest quality

Resumo: A busca por alternativas para aumentar a vida útil de frutas utilizando revestimentos biodegradáveis tem crescido nos últimos anos, especialmente para frutas cujo processo de amadurecimento continua após a colheita, como no caso da banana. Objetivou-se com esse estudo avaliar a conservação de bananas 'Prata Anã' revestidas com fécula de mandioca e pectina, durante o armazenamento em temperatura ambiente. As bananas foram selecionadas, lavadas e revestidas com soluções de fécula e de pectina nas concentrações de 0 (controle) 2, 5 e 8% e armazenados a 25 ± 3°C por doze dias, avaliando-se a cada três dias quanto à perda de massa, cor da casca, firmeza do fruto, sólidos solúveis totais, acidez total titulável e potencial hidrogeniônico. O delineamento experimental foi inteiramente casualizado em esquema fatorial 7 x 5 (concentrações dos revestimentos x períodos de armazenamento), com três repetições. Os resultados foram submetidos à análise de variância, análise de regressão e as médias comparadas pelo teste de Tukey a 5% de probabilidade. Os revestimentos a base de fécula de mandioca e pectina caracterizaram-se como boas alternativas para aumentar a vida útil de bananas 'Prata Anã'. As concentrações de 5 e 8% dos dois revestimentos analisados destacaram-se na conservação de alguns atributos de qualidade dos frutos como, coloração, firmeza e sólidos solúveis totais. Considerando a relação custo/benefício o uso do revestimento à base de fécula seria mais apropriado.

Palavras-chave: *Musa* AAB, revestimento biodegradável, qualidade pós-colheita

Introduction

Brazil is one of the world's largest producers of bananas (*Musa* spp.), with a production of 6.96 million tons in 2016 in a cultivated area of 474,054 thousand hectares (Carvalho et al., 2017). Among the cultivars most produced in the national territory, the 'Prata Anã' is present in the main producing regions and, together with the cultivars 'Pacovan' and 'Prata', represent more than 60% of the area planted with bananas (Lessa et al., 2012), with emphasis on the Northeast region.

In Brazil, post-harvest losses of bananas may reach 42% (Reetz et al., 2015). The main causes are failures in the cultivation process, incorrect harvesting stage, inadequate storage and packing, bad conditions of transportation and lack of fruit conservation technologies (Borges et al., 2004).

Many methods have been developed to delay fruit deterioration, such as the use of edible and biodegradable coatings, which may reduce metabolic activities, water loss, wilting and mechanical damage caused by transport, increasing shelf life and improving fruit appearance, often providing them with a superficial shine (Togrul and Arslan, 2004; Silva et al., 2011). In addition, the use of coatings has been gaining prominence in the market because it is a good alternative to reduce environmental impacts due to the possibility of replacing plastic packaging (Pimentel et al., 2011).

The most used coatings in edible fruits and vegetables are edible materials such as polysaccharides (starch and derivatives, cellulose and its derivatives, pectin, carrageenan and alginate), proteins (myofibrillar proteins, gelatin, casein, gluten wheat, zein and ovalbumin) and lipids (acetylated monoglycerides, stearic acid, waxes and fatty acid esters) (Luvielmo and Lamas, 2012).

The cassava starch-based coating appears as a viable alternative mainly to the Brazilian northeast, which stands out in the production of this material. Sarmento et al. (2006), for example, verified that the application of cassava starch influenced the physical and physical-chemical characteristics of 'Prata Catarina' bananas stored in ambient conditions, increasing the shelf life in relation to a control.

Studies have been conducted using pectin at post-harvest in tomatoes, for example, in which the use of this edible coating at different concentrations has been shown to be effective in delaying the development of the typical staining of mature tomatoes (Oliveira et al., 2012). Nevertheless, studies on this type of coating in bananas are scarce; it becomes relevant an investigation of new possibilities that help in the delay of the maturing of these fruits.

Thus, the objective of this work is to evaluate the effects of cassava and pectin starch coating at different concentrations on the conservation of ‘Prata Anã’ bananas stored at room temperature.

Materials and Methods

The bananas of the cultivar ‘Prata Anã’ originated from the Salitre Irrigated Perimeter (9º31'S, 40º15' W). The fruits were harvested at stage 1 (totally green), pre-washed in the field and taken to the Agricultural Products Storage Laboratory of the Federal University of Vale do São Francisco, Juazeiro, BA, where they were selected and washed again with detergent (1:10 v/v) and dried at room temperature.

After separation in bouquets of three bananas, they were immersed into solutions of cassava starch and pectin at concentrations of 0, 2, 5 and 8% for one minute and arranged in trays under artificial ventilation to dry. The cassava starch solutions were obtained by gelation of starch in water heated at 70°C under constant stirring for 15 minutes, according to Santos et al. (2011). Pectin solutions were homogenized in a blender for 30 seconds until gelation as proposed by Oliveira et al. (2012).

After drying, the fruits were conditioned at room temperature (25 ± 3°C and 68 ± 4% RH) for 12 days. The bananas were analyzed every three days in storage as for weight loss, peel color, fruit firmness, total soluble solids (TSS), total titratable acidity (TTA) and potential of hydrogen (pH).

The mass loss was determined with a semi-analytic balance with a precision of 0.01 g and the results were expressed as percentage. To evaluate peel color, a portable digital colorimeter Konica Minolta DP-400 was used, and the changes were quantified according to the parameters L*, a* and b*, which indicate, respectively, brightness (L*), red (a*), green (-a*), yellow (b*) and blue hues (-b*).

Fruit firmness was determined with a digital penetrometer (PTR 300) with a tip diameter of 8 mm. One reading was performed per fruit in the middle region, and the results were expressed in Newtons (N).

Total soluble solids (TSS) were determined by direct reading using a digital refractometer (Invert Sugar Refractometer HI 96804), and the results were expressed in °Brix. Total titratable acidity was determined by titrating the sample with a sodium hydroxide solution (0.1 M NaOH) using 1% phenolphthalein (IAL, 2008). The results were expressed as percent of malic acid. The potential of hydrogen (pH) was determined with a benchtop pH meter (Hanna HI 221) according to techniques recommended by the IAL (2008).

The experimental design was completely randomized in a 7 x 5 factorial design consisting of seven coating concentrations (three concentrations of starch solution: 2, 5 and 8%, and three concentrations of pectin solution: 2, 5 and 8%, plus the control) and five storage periods (0, 3, 6, 9 and 12 days) with three replications, each consisting of one fruit. The results were submitted to analysis of variance and regression analysis, and the means

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were compared by Tukey test at 5% probability using the statistical software Assistat version 7.7 beta (Silva and Azevedo, 2016).

Results and Discussion

The mass loss of 'Prata Anã' bananas was not influenced by the interaction between coating types and storage time. By analyzing separately the effects of coatings (Figure 1A), it was observed that, except for 5% pectin, the other coatings reduced the mass loss of banana fruits when compared to the control (18.7%), regardless of the storage period, being 13.1, 12.3, 10.0, 12.9, 12.8% for bananas coated with 2.5% and 8% starch and pectin at 2 and 8%, respectively. Differing from the results found, Silva et al. (2011) did not verify the influence of the use of gelated cassava starch at different concentrations when refrigerated, which did not represent a barrier to the loss of 'Prata' banana moisture.

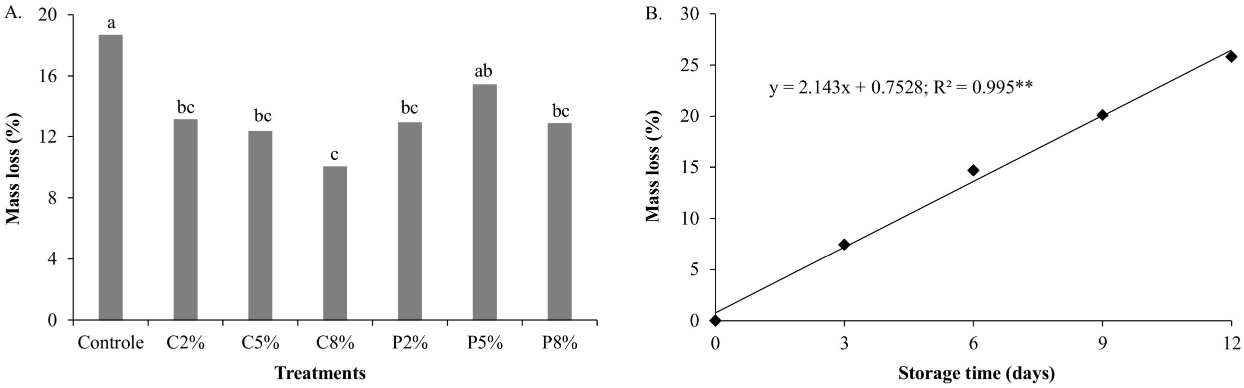

Figure 1. Mass loss (%) of 'Prata Anã' bananas coated with cassava starch and pectin at concentrations of 0% (control), 2, 5 and 8% (A) in function of storage time at room temperature (B). C - Cassava starch and P - Pectin. Means followed by the same letter do not differ statistically by Tukey test at 5% probability.

Montibeller et al. (2016), however, studying coatings made with natural polymers on the conservation of bananas 'Caturra', found a decrease in the rate of mass loss during the storage period of fruits coated with pectin, a vegetable biopolymer with a great capacity to thicken and stabilize emulsions, contributing to the formation of a thick film around bananas.

When the time effect (Figure 1B) was analyzed, regardless of the treatment used, the bananas lost mass linearly during the twelve days of storage. This demonstrates that the coatings tested are not water vapor-proofed barriers, as verified by Oshiro et al. (2012) for 'Pedro Sato' guavas coated with gelatin and chitosan, and Costa et al. (2016) evaluating the quality of 'Palmer' mangoes coated with solutions of cassava starch at 1, 2 and 3%.

Fruit luminosity oscillations for all treatments were not accentuated until the ninth day of storage. At the end of the period (day 12), the bananas coated with starch or pectin at 2% presented lower values, indicating the appearance of darker shades during storage, which did not occur with fruits coated with the other concentrations, which may influence consumer preference.

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Table 1. Luminosity (L*) of the peel of 'Prata Anã' bananas coated with cassava starch (C) and pectin (P) at concentrations of 0% (control), 2, 5 and 8% (A) during the storage time at room temperature.

Treatments	Storage time (days)				
	0	3	6	9	12
0% (Controle)	45,94 aA	46,52 aA	54,76 abA	50,97 abA	55,76 aA
C2%	45,94 aB	45,27 aB	60,81 aA	58,09 aA	22,75 bC
C5%	45,94 aA	53,28 aA	46,37 bA	46,20 bA	52,54 aA
C8%	45,94 aA	46,50 aA	49,32 bA	54,05 abA	48,31 aA
P2%	45,94 aA	45,04 aA	50,96 abA	49,77 abA	22,15 bB
P5%	45,94 aA	43,44 aA	52,02 abA	48,80 abA	53,05 aA
P8%	45,94 aB	45,07 aB	49,22 bAB	45,73 bB	56,18 aA

MG = 47.84381; CV = 8.99%; $DMS_{columns}$ = 10.6538; DMS_{rows} = 9.8414. Means followed by the same lowercase letters in columns and uppercase in rows do not differ statistically by Tukey test at 5% probability.

The green coloration of fruit peels coated with 5% starch or 5 and 8% pectin did not significantly change throughout the storage time (Table 2). We may infer that, even at room temperature, the degradation of chlorophyll and possibly other metabolic processes have been delayed, which may lead to a longer product shelf life. According to Sarmento et al. (2015), this behavior can be explained by the lower passage of O_2 inside the coated fruits, as verified by the authors when storing 'Prata Catarina' bananas coated with 3% pectin starch.

Table 2. Color component a* (intensity of green) of the peel of 'Prata Anã' bananas coated with cassava starch (C) and pectin (P) at concentrations of 0% (control), 2, 5 and 8% during the storage time at room temperature.

Treatments	Storage time (days)				
	0	3	6	9	12
0% (Controle)	-15,65 aC	-5,06 aB	-3,21 aB	1,20 aA	2,18 bA
C2%	-14,93 aC	-13,55 cC	-2,93 aB	-0,84 aB	6,26 aA
C5%	-14,93 aA	-13,84 cA	-15,79 bA	-13,34 bA	-12,49 cA
C8%	-14,93 aB	-13,07 cAB	-14,47 bB	-12,01 bAB	-10,76 cA
P2%	-14,93 aD	-8,48 abC	-0,27 aB	2,33 aB	6,16 aA
P5%	-14,93 aA	-13,13 cA	-14,59 bA	-11,90 bA	-13,16 cA
P8%	-14,93 aB	-11,44 bcA	-12,35 bAB	-13,30 bAB	-12,69 cAB

MG = 10.59952; CV = 13.81%; $DMS_{columns}$ = 3.6246; DMS_{rows} = 3.3482. Means followed by the same lowercase letters in columns and uppercase in rows do not differ statistically by Tukey test at 5% probability

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At the end of storage, bananas coated with starch or pectin at the lowest concentration (2%) had a greater loss of green (Table 2) and less yellowish tones (Table 3), which, together with less light, as mentioned above, may result in the browning of the peel.

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Table 3. Color component b* (intensity of yellow) of the peel of ‘Prata Anã’ bananas coated with cassava starch (C) and pectin (P) at concentrations of 0% (control), 2, 5 and 8% during the storage time at room temperature.

Treatments	Storage time (days)				
	0	3	6	9	12
0% (Controle)	30,44 aB	30,47 aB	39,42 aA	33,77 abAB	38,32 aA
C2%	30,44 aBC	27,19 aC	36,88 aAB	39,96 aA	10,97 cD
C5%	30,44 aA	28,10 aA	29,47 bA	26,47 bcA	29,40 bA
C8%	30,44 aA	26,47 aA	28,58 bA	28,04 bcA	28,25 bA
P2%	30,44 aB	30,63 aB	37,63 aA	25,44 cB	11,70 cC
P5%	30,44 aA	26,74 aA	29,31 bA	28,36 bcA	32,26 abA
P8%	30,44 aAB	24,34 aB	25,68 bAB	26,42 bcAB	32,40 abA

MG = 29.30681; CV = 10.20%; DMS_{column} = 7.4039; DMS_{rows} = 6.8393. Means followed by the same lowercase letters in columns and uppercase in rows do not differ statistically by Tukey test at 5% probability.

In agreement with the color component a*, the b* component of the peel did not change significantly during the storage of coated bananas at higher concentrations of starch or pectin (5 and 8%), thus not increasing the intensity of yellow, a change observed in the ripening of these fruits, as can be seen for uncoated fruits (control).

When firmness was analyzed, it was found that it decreased progressively for bananas submitted to the different treatments during the twelve days of storage (Figure 2). Regardless of the type of coating used, the reduction in fruit firmness will occur naturally, as it is related to enzymatic activities, water loss along with degradation of the cell wall throughout ripening and, in fruits such as mango and banana, to degradation of the starch (Vilas Boas et al., 2004; Sarmento et al., 2015).

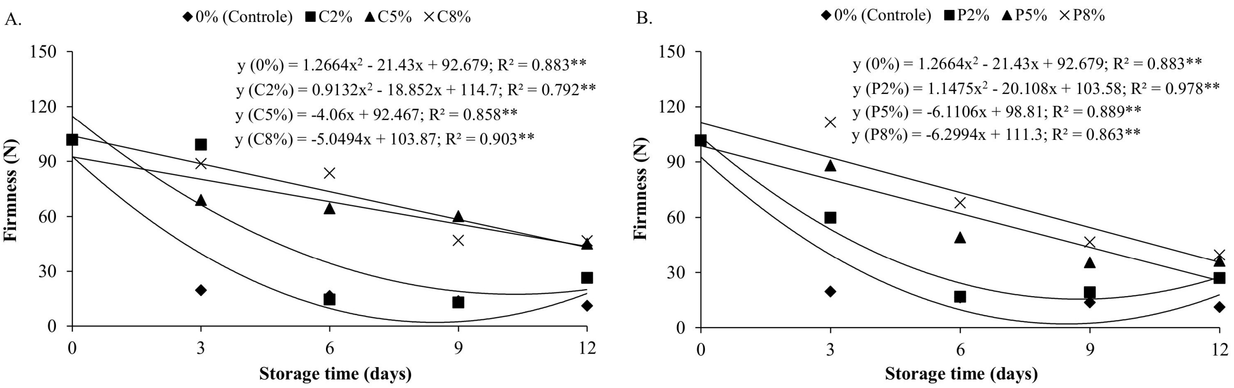

Figure 2. Firmness of ‘Prata Anã’ bananas coated with cassava starch (A) and pectin (B) at concentrations of 0% (control), 2, 5 and 8% (A) in function of storage time at room temperature. C - Cassava starch and P - Pectin.

However, the fruits that kept a greater firmness were those coated with cassava starch at concentrations 5 and 8% (Figure 2A), or with pectin 5 and 8% (Figure 2B), from 101.7 N at the beginning to 45.2, 46.8, 36.3, 39.6 N at the end of storage. It is inferred that increasing the concentration of the substances in the coatings may delay the senescence process of the bananas, as well as provide a greater mechanical protection, as verified by Montibeller et al. (2016) by coating bananas with pectin, potato starch, xanthan, carrageenan and albumen, to the detriment of gelatin and corn starch, for example.

As for total soluble solids, although an increase was observed for both coated fruits and uncoated fruits, when 5% and 8% cassava starch and

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8% pectin were used, the increase was lower (Figure 3). This indicates that the use of these concentrations may delay the hydrolysis of starch and the consequent release of single sugar molecules (Simões, 2014), indicating a slower ripening process and consequently a longer shelf life when this quality attribute is analyzed during storage.

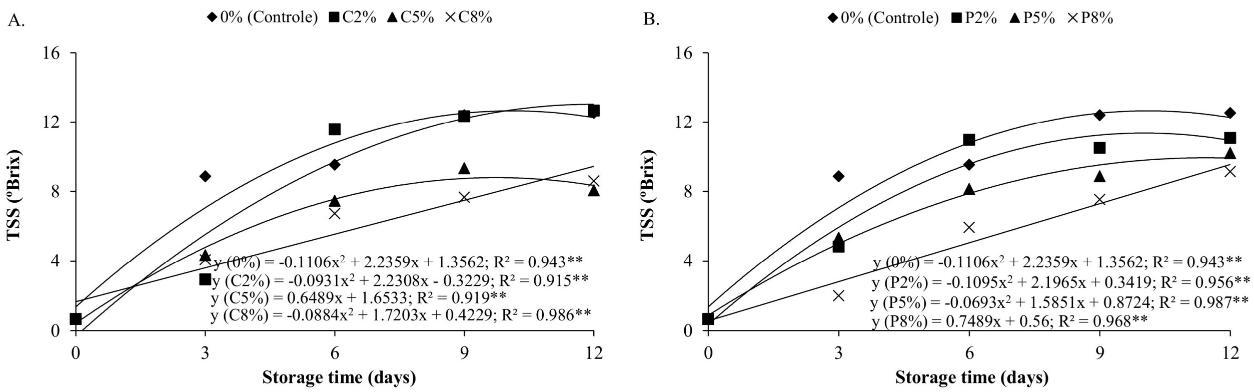

Figure 3. Total soluble solids (TSS) of 'Prata Anã' bananas coated with cassava starch (A) and pectin (B) at concentrations of 0% (control), 2, 5 and 8% (A) in function of storage time at room temperature. C - Cassava starch and P - Pectin.

With increasing concentrations, the difference in soluble solids content was greater for cassava starch than for pectin. The results corroborate those found by Silva et al. (2015), who coated bananas of 'Maçã' variety with cassava starch. The authors observed that the fruits with no coating (0%) had a higher content of soluble solids (15.2 ºBrix), whereas fruits that were coated at the concentration of 8% presented a lower soluble solids content (16.9 °Brix), emphasizing that the cassava starch-based coating reduced the degradation of polysaccharides by respiration.

The titratable acidity tended to increase during the storage of bananas regardless of the treatment used. In contrast to other fruits, such as tomatoes and mangoes, where there is a decrease in acidity during ripening (Oliveira et al., 2015; Serpa et al., 2014; Costa et al., 2017), in 'Prata Anã' bananas there was an increase of acid, an event associated to the reduction of the activity of malate oxidase and the respiration itself, which produces organic acids that may accumulate in the fruit (Aroucha et al., 2010; Pimentel et al., 2010).

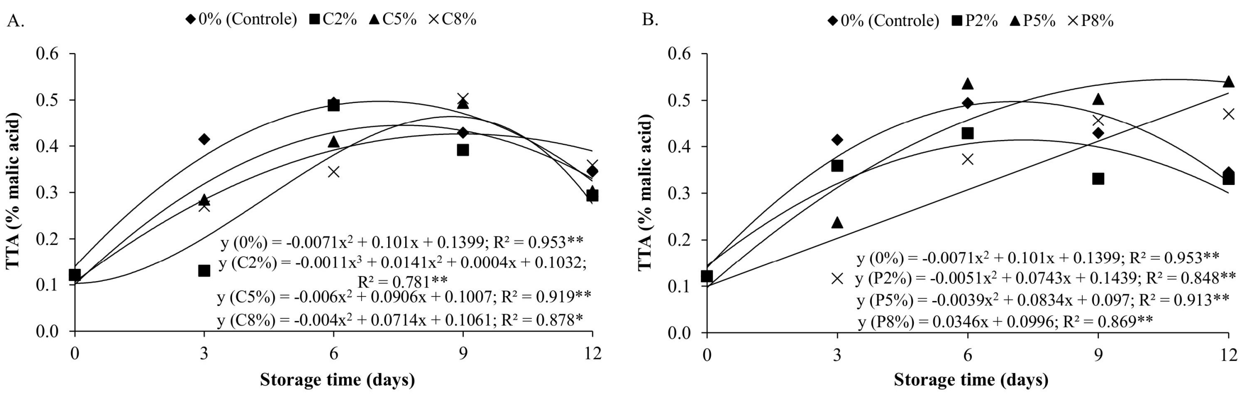

Figure 4. Total titratable acidity (TTA) of 'Prata Anã' bananas coated with cassava starch (A) and pectin (B) at concentrations of 0% (control), 2, 5 and 8% (A) in function of storage time at room temperature. C - Cassava starch and P - Pectin.

At the end of the storage, starch-coated fruits had generally lower acidity levels compared to those coated with pectin. In addition, the production of organic acids possibly increased mainly up to the 9th day of storage, tending to a reduction of pH (Figure 5), as evidenced by Silva et al. (2015). On the 12th day of storage, the bananas coated with 5% pectin had a lower average pH value (4.84) compared to the other treatments, for example the pH of fruits coated with starch at the same concentration, which was 5.73.

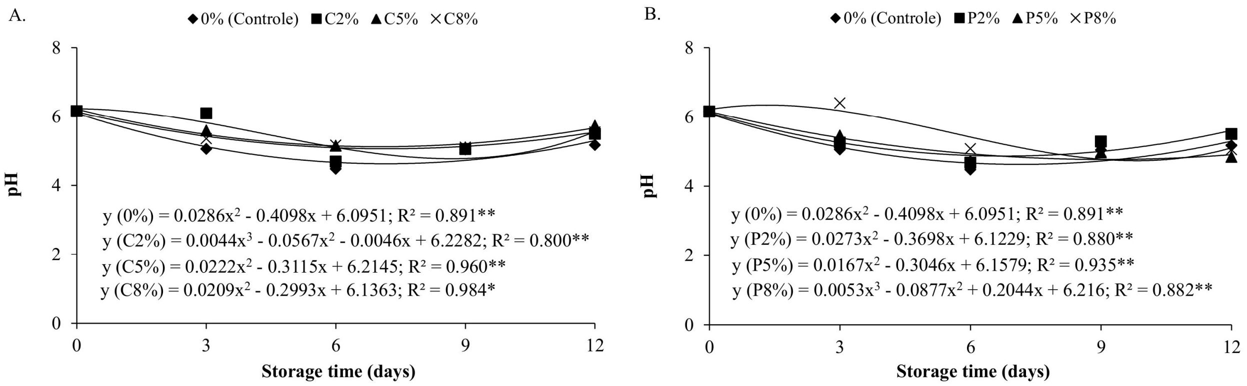

Figure 5. Potential of hydrogen (pH) of 'Prata Anã' bananas coated with cassava starch (A) and pectin (B) at concentrations of 0% (control), 2, 5 and 8% (A) in function of storage time at room temperature. C - Cassava starch and P - Pectin.

Conclusions

The coatings based on cassava starch and pectin were characterized as possible alternatives to increase the shelf life of 'Prata Anã' bananas.

The concentrations 5 and 8% of both coatings stood out in the preservation of some fruit quality attributes such as color, firmness and total soluble solids. Considering the cost/benefit ratio, the use of starch-based coatings would be more appropriate.

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